

A Real-Time Data Assimilation System Based on MICOM/HYCOM

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Persons visited

Alan Walkraft, NRL Stennis

Rainer Bleck, Los Alamos National Laboratory

Andrew Bennett, NRL Monterey

DIADEM real time experiment: <http://diadem.halo.is/diadem/rtweb.html>

Nansen Center homepage: <http://www.nrsc.no>

LONG TERM GOALS

To develop an operational ocean and ecosystem monitoring and prediction system for the North Atlantic, Nordic Seas and Arctic Ocean, using state of the art numerical model tools and data assimilation methodologies.

To extend and further develop the existing data assimilation system to handle new or upcoming types of in situ and satellite data that can give valuable information for the prediction of physical and biochemical variables in the ocean.

To integrate these capabilities to establish a forecasting capability for nested regional model domains which can be used to support off shore industry operating along and off the continental shelf.

OBJECTIVES

A project funded under the National Oceanographic Partnership Program (NOPP) focuses on the development of data assimilation capabilities for the Hybrid Coordinate Ocean Model (HYCOM). The project involves a number of partners including NRL at Stennis and Los Alamos National Laboratory. Further, there are extensive data assimilation activities going at the NRL in Monterey. The purpose of this effort was to visit these labs and:

1. To present a real time ocean monitoring and forecasting system that has been developed in the EC-funded DIADEM-project. A seminar was held at all labs and the purpose was to share personal experience with advanced data assimilation systems and to have fruitful discussions with other scientist working in the same field.
2. To obtain an overview of ongoing and future ocean modelling and data assimilation activities within operational oceanography in the US.
3. Discuss progress and future perspectives in data assimilation for operational oceanography.

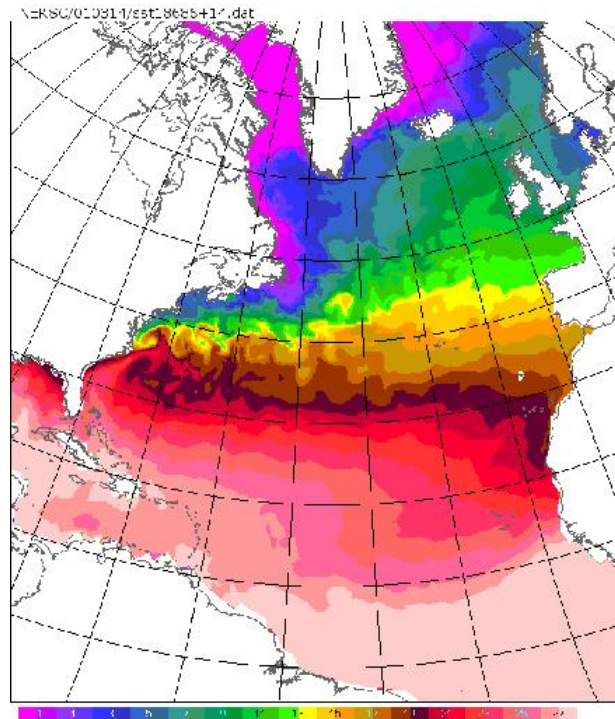


Figure 1: Forecast from the DIADEM real time ocean monitoring and forecasting system. The plot is downloaded from the public website and shows the sea surface temperature forecast for March 14th 2001.

APPROACH

Two projects, funded by the European Commission, focus on developments of an operational ocean monitoring and prediction system for the North Atlantic, the Nordic Seas and the Arctic Ocean. These are the DIADEM and TOPAZ projects which are both coordinated by Prof. Geir Evensen at the Nansen Environmental and Remote Sensing Center in Bergen, Norway.

The EC MAST-III project DIADEM focuses on the implementation of sophisticated data assimilation methodologies with an ocean general circulation model and a marine ecosystem model.

The models used in DIADEM is a version of the Miami Isopycnic Coordinate Ocean Model (MICOM) developed by Bleck et al., (1992) at the University of Miami, and a 3-dimensional implementation of the ecosystem model by Fasham et al. (1990) which has been coupled with MICOM by Drange (1994, 1996). Remotely sensed sea-surface heights and temperatures are assimilated in the physical model, while ocean color data are used for assimilation in the ecosystem model.

The data assimilation methods are all based on dynamically consistent estimates of error statistics, and have now been validated in a hind-cast experiment. These are the Ensemble Kalman Filter (Evensen, 1994), the Ensemble Kalman Smoother (Evensen and van Leeuwen,

2000), and the Singular Evolutive Extended Kalman Filter (Pham et al., 1998). The use of so-called advanced methods have introduced the possibility of performing a multivariate and physically consistent analyses with statistical covariance functions varying in space and time. This allows us to extract a maximum amount of information from satellite observations of surface quantities, since vertical projection of information is controlled by the dynamically evolving error covariances in the system.

The system has recently been set up for real time operation for the period, Nov 2000 to May 2001. The assimilation systems for the physical model was first introduced and later on the assimilation for the ecosystem model will be included in time to capture the spring bloom in 2001. The real time operation is clearly feasible with the availability of remote sensing products in near real time, and atmospheric forcing fields from the meteorological forecasting centers. During the real time operation the DIADEM results will be displayed on the DIADEM web page <http://diadem.halo.is/diadem>.

Thus, the DIADEM project has for the first time established an operational capability for coupled physical and ecosystem modeling in the North Atlantic and the Nordic Seas, where satellite information is assimilated using advanced data assimilation methods.

The project involves seven European partners:

1. The Nansen Environmental and Remote Sensing Center (NERSC) is coordinating the project and is supplying the model systems used by all partners. NERSC is responsible for model validation and an implementation of the Ensemble Kalman Filter (Evensen, 1994) with MICOM and the ecosystem model used.
2. The Institute for Marine and Atmospheric Research, University of Utrecht (IMAU), is implementing the Ensemble Kalman Smoother (Evensen and van Leeuwen, 2000) with the physical model.
3. The Universite Joseph Fourier, Laboratoire des Ecoulements Geophysiques et Industriels, (LEGI) is developing a Singular Evolutive Extended Kalman Filter (Pham et al., 1998) with the MICOM model and the ecosystem model.
4. Calibration of the model parameters in the ecosystem model is done by the Alfred Wegener Institute (AWI).
5. The remote sensing data are processed and delivered by Collecte Localisation Satellites (CLS) and the Joint Research Centre (JRC).
6. The HALO Laboratory for Oceanic and Atmospheric Sciences is maintaining the project web-page (<http://jaki.halo.is/diadem>) where the forecasts from the assimilation systems will be displayed, and also develop a marine information system which will be used for the data management in the project.

A sea surface temperature forecast from the DIADEM prediction system is shown in Figure 1. The plot shows the sst forecast for March 14th 2001. It has been produced at NERSC, using a high resolution MICOM version and a weekly EnKF data assimilation of Topex/Poseidon-ERS2 altimetry and Reynolds sst.

A new project TOPAZ has recently been funded by the European Commission under the fifth Framework Program. TOPAZ extends the developments of DIADEM to a more realistic

operational system. It involves the assimilation of in situ data from the ARGO program as well as other remote sensing products such as ice concentration (SSM/I), ice thickness (Cryosat), sea surface salinity (SMOS) and the improved SLA data which can be derived with the new geoid from the GOCE mission. In addition, the MICOM model used in DIADEM will now be replaced by the recent Hybrid Coordinate Ocean Model (HYCOM). This model integrates the properties of the isopycnal MICOM model for the deep ocean with a level model for the surface boundary layer. Thus it is designed to work equally well for the coastal shelf areas as for the deep ocean. With the inclusion of a nesting capability the TOPAZ project will develop a state of the art operational ocean prediction system. The partnership in TOPAZ is the same as for DIADEM but excluding IMAU and JRC. Finally it should be stated that the DIADEM and TOPAZ projects comply with, and contribute to, the plans of international programs such as GODAE and EuroGOOS.

TRAVEL COMPLETED

Table 1. Summary of visits conducted under this VSP

Person visited	Position	Institution	Location	Purpose	Dates
Alan Wallcraft	Dr.	NRL	Stennis	HYCOM model, data assimilation	31/01-01 to 02/02-01
Rainer Bleck	Prof.	LANL	Los Alamos	HYCOM model, data assimilation	03/02-01 to 06/02-01
Andrew Bennett	Prof.	NRL	Monterey	HYCOM model, data assimilation	07/02-01 to 10/02-01

RESULTS

We obtained positive feedback on the DIADEM real time ocean forecasting system and had interesting discussions about the Ensemble Kalman Filter data assimilation technique and other Monte Carlo based assimilation techniques, both at NRL at the Stennis Center and especially with Prof. Andrew Bennett and coworkers at NRL Monterey. Moreover, I personally obtained deeper insight into other relevant assimilation methodologies that are frequently used within research and operational oceanography and meteorology. Here I mention only a few; the development of the NRL Atmospheric Variational Data Assimilation System (NAVDAS) which is based on 3DVAR assimilation and the extension to 4DVAR (at NRL, Monterey). In addition, a system for variational assimilation of data into the ocean model has been developed by Bennett et al. at the Fleet Numerical Meteorology and Oceanography Center, Monterey. We also shared our experiences within data assimilation and ocean forecasting with the NRL employees in Mississippi. At the Stennis Center we got a valuable presentation of the NLOM global ocean forecasting system and had the opportunity to discuss data assimilation with ocean models in general. In addition, we discussed OPEN MP parallelisation and future developments of the HYCOM model with Dr. Alan Wallcraft. At LANL, Prof. Rainer Bleck and his group presented their work on climate modeling with MICOM and HYCOM.

Future collaboration between NERSC and the NRLs seems to be of interest for both parts. Recently an ONR proposal on real time forecasting of ocean variables for submarines has been

submitted by NERSC. If this proposal gets funded, a strong cooperation between NERSC and NRLs will follow.

IMPACT/APPLICATIONS

Due to the similar objectives within operational oceanography in the European DIADEM and TOPAZ projects and the US NOPP HYCOM project, but the rather different approaches taken, in particular within data assimilation, there is a clear potential for a new joint project focusing on technology transfer. Clearly the two systems being developed, will be further improved by additional interaction and exchange of information and technology.

TRANSITIONS

There is an obvious potential for technology transfer related to particular modules in the HYCOM model system and the assimilation implementations. This will be ensured by further interaction with US scientists in the HYCOM consortium.

RELATED PROJECTS

DIADEM (EC MAST–III): Development of Advanced Data Assimilation Methods for MICOM in a setup for the North Atlantic and Nordic Seas.

TOPAZ (EC Framework Program V): Extension of DIADEM to use the HYCOM model and more input data including ARGO floats and ice observations in the Arctic. Further down-scaling to coastal zones by introducing nested sub domains.

NOPP: US initiative for developing operational modeling and data assimilation

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